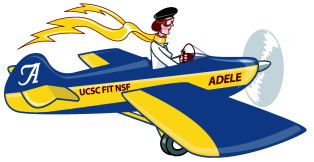
High-energy radiation from thunderstorms

Airborne
Detector for
Energetic **L**ightning **E**missions

David M. Smith, Nicole Kelley, Gregory Bowers, Paul Buzbee, Forest Martinez-McKinney, and Audrey Chou
UCSC SCIPP/Physics

Joseph R. Dwyer, Michael Splitt, Steven Lazarus, Hamid Rassoul
Florida Institute of Technology

ADELE is funded by the National Science Foundation

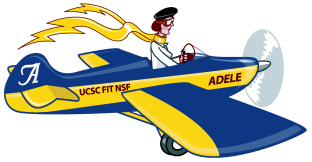


Three questions:

Is there a role for particle acceleration and high-energy radiation in the initiation and propagation of lightning leaders?

What is the fundamental limit of electric fields in air?

How do Terrestrial Gamma-ray Flashes (TGFs) work?



Acceleration of electrons to high energy in air:

Electric field is here: all e- run away

Electric field is here: e- > 10 keV run away

Typical of t-storm fields!

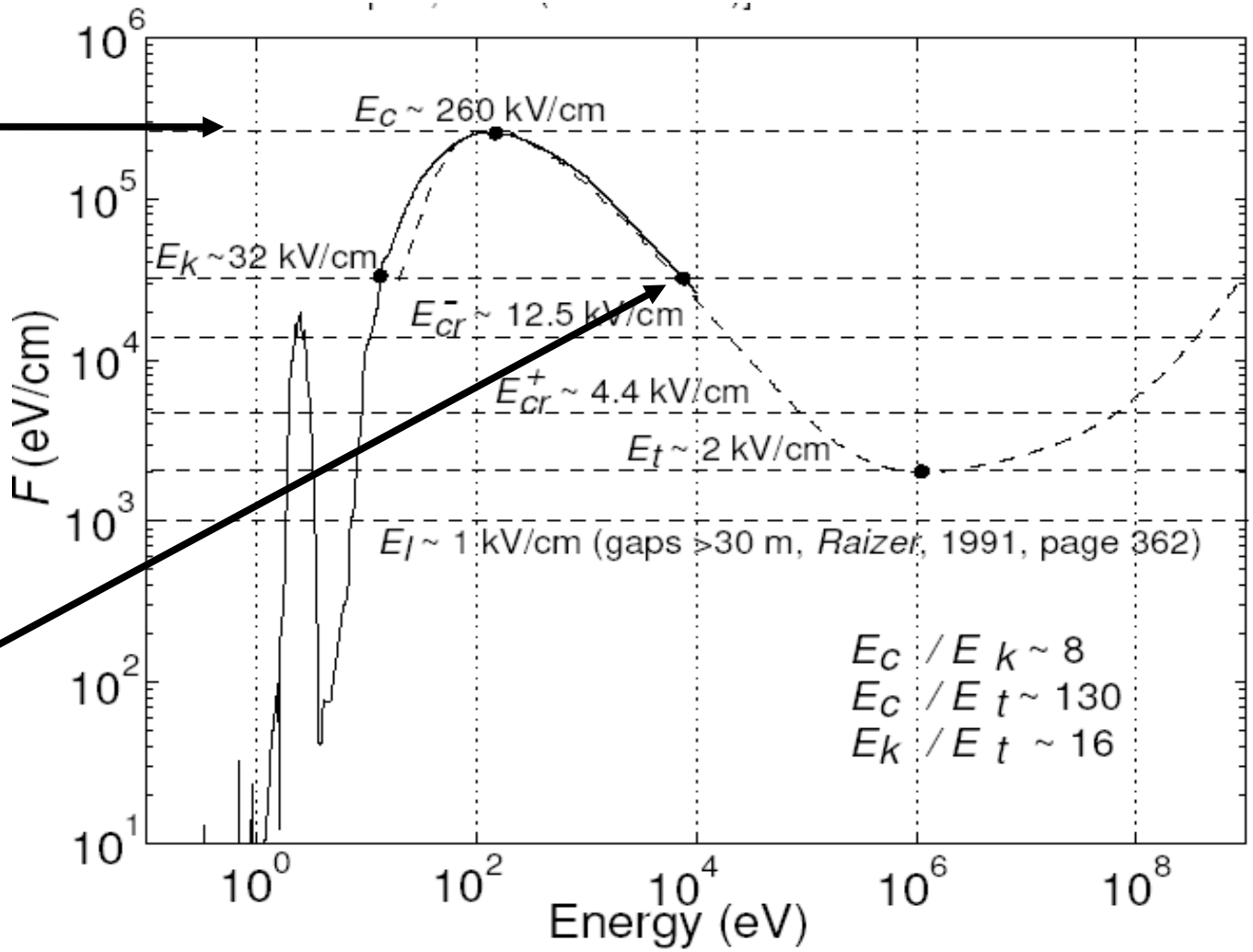
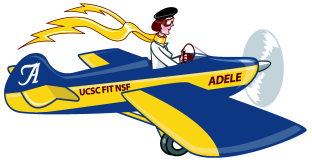


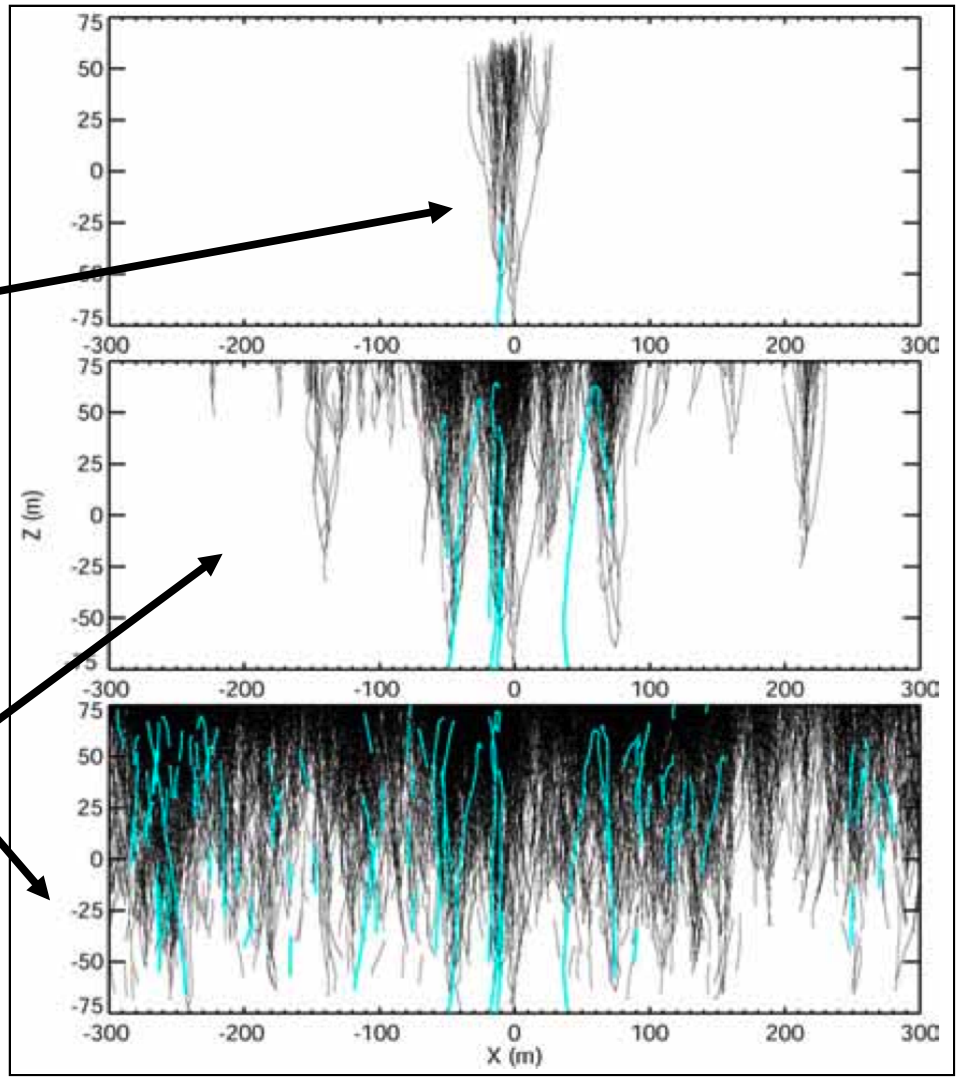
Figure by V. Pasko, from tutorial at the NATO summer institute on Sprites, etc., Corte, Corsica, 2004

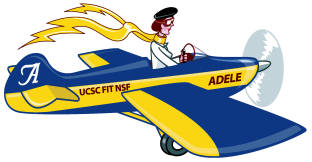


Runaway electrons predicted by C. T. R. Wilson (of cloud chamber fame) in 1925

Runaway *avalanche* hinted at by Wilson but developed by Gurevich and collaborators in 1992

Runaway *breakdown* (avalanche of avalanches until the field breaks down) proposed by J. Dwyer in 2003



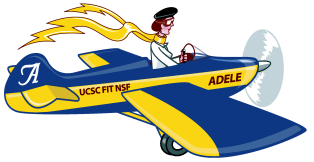


Classes of high-energy observations

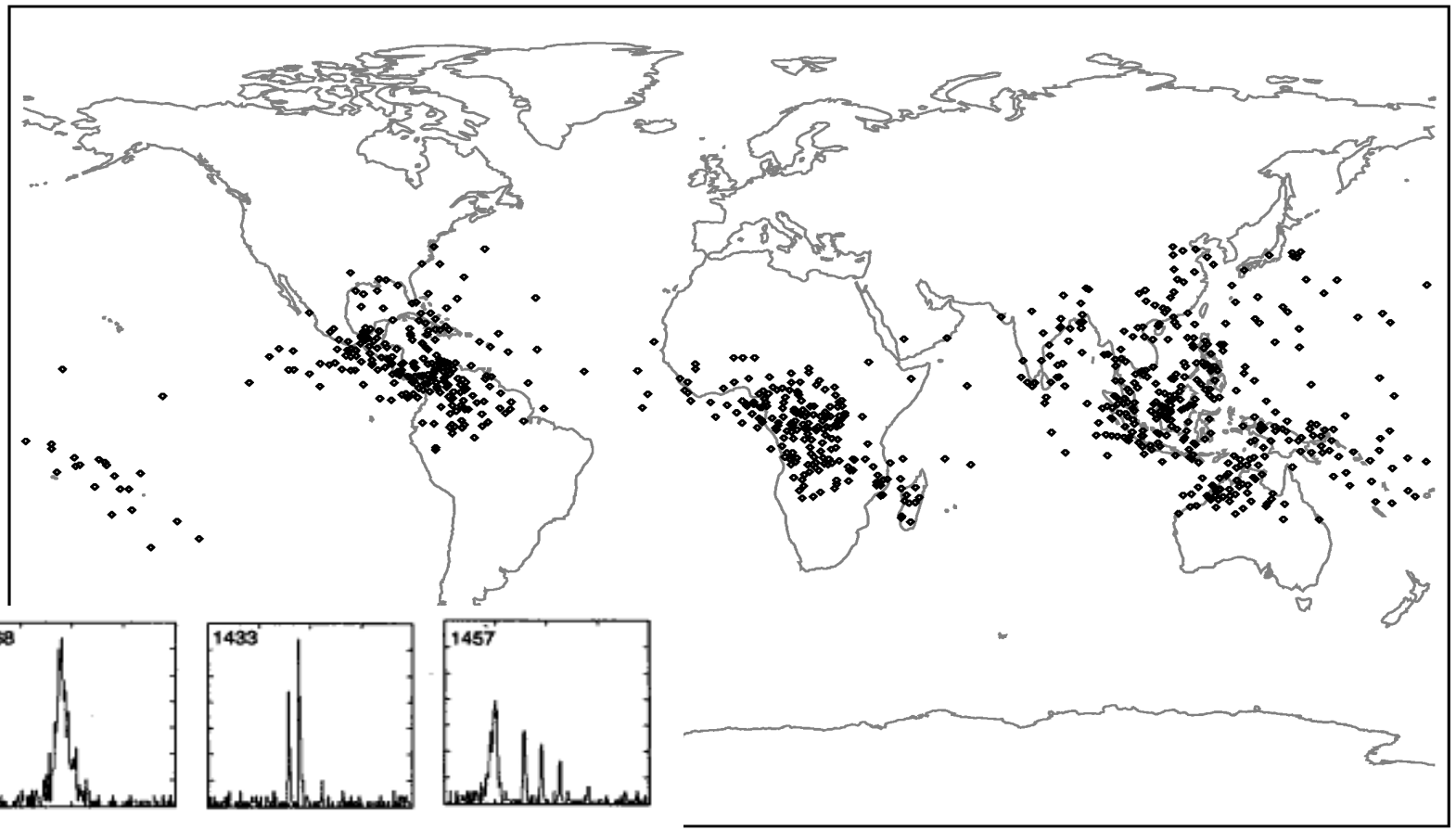
Glows: second-to-minute enhancements seen from ground, balloons, aircraft – runaway without breakdown? Do they compete with lightning to limit the E-field in storms?

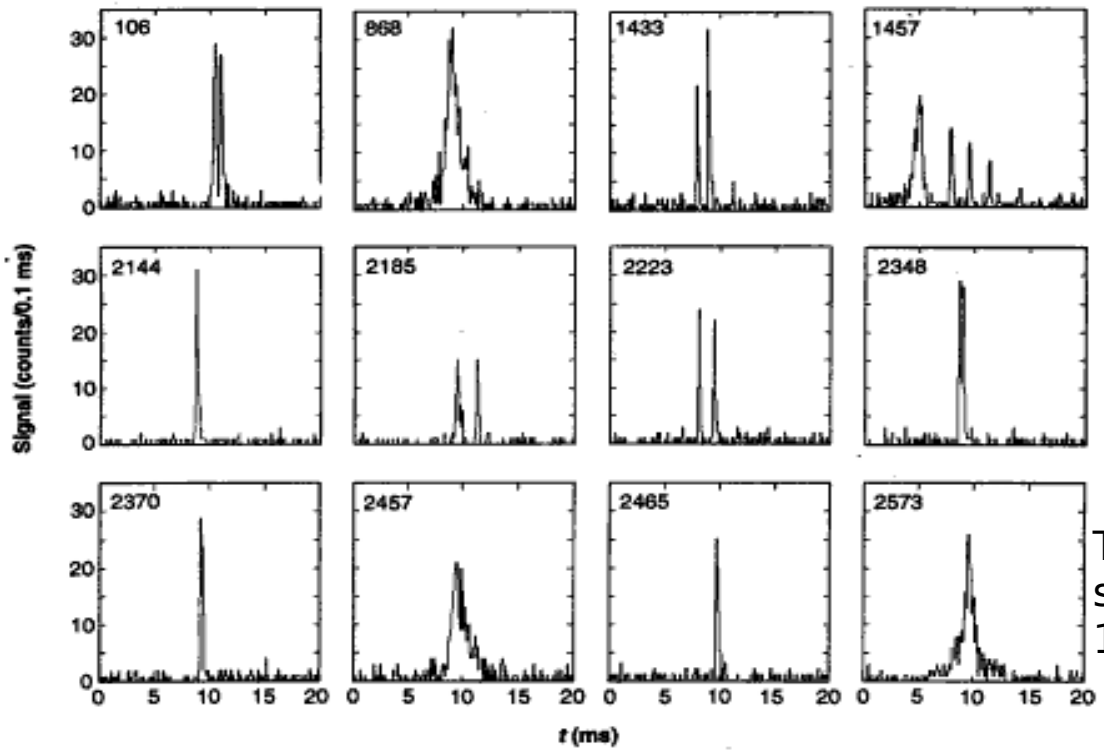
Steps: Microsecond bursts of x-rays associated with lightning leader propagation. Do they happen in upward lightning (jets)?

Terrestrial Gamma-ray Flashes – millisecond duration, POWERFUL – MeV energies – true runaway breakdown?



TGF map from RHESSI satellite data





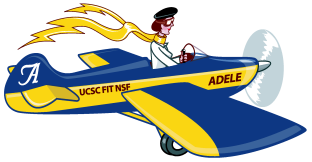
Terrestrial Gamma-ray Flashes (TGFs)

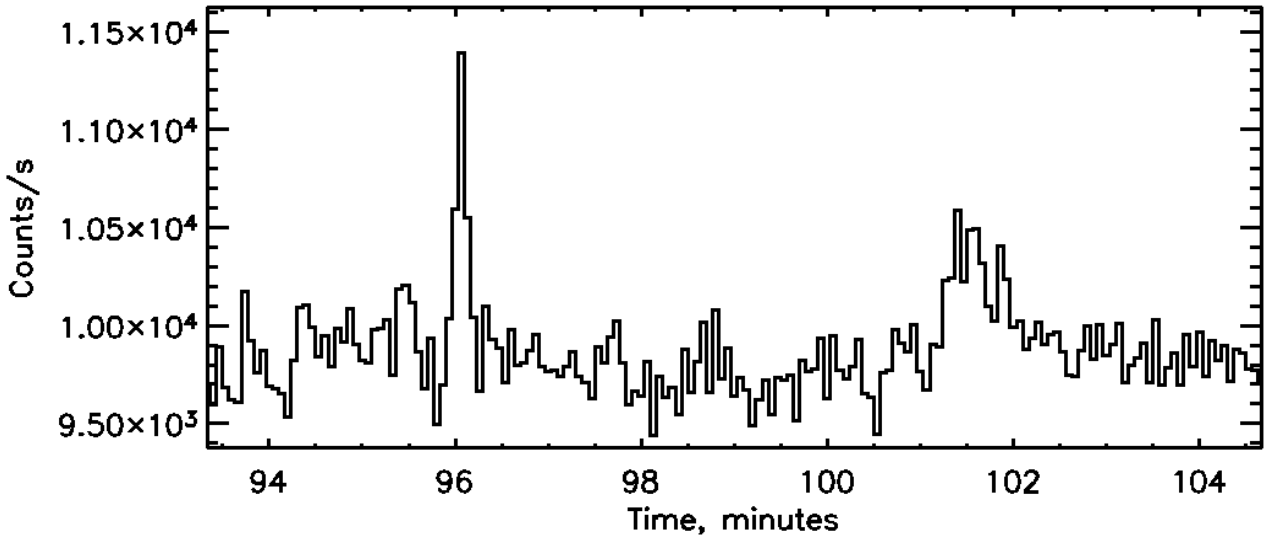
TGF time profiles from BATSE satellite data (Fishman et al. 1994, *Science*

TGF radiation doses may be a rare health hazard to airline crew and passengers.

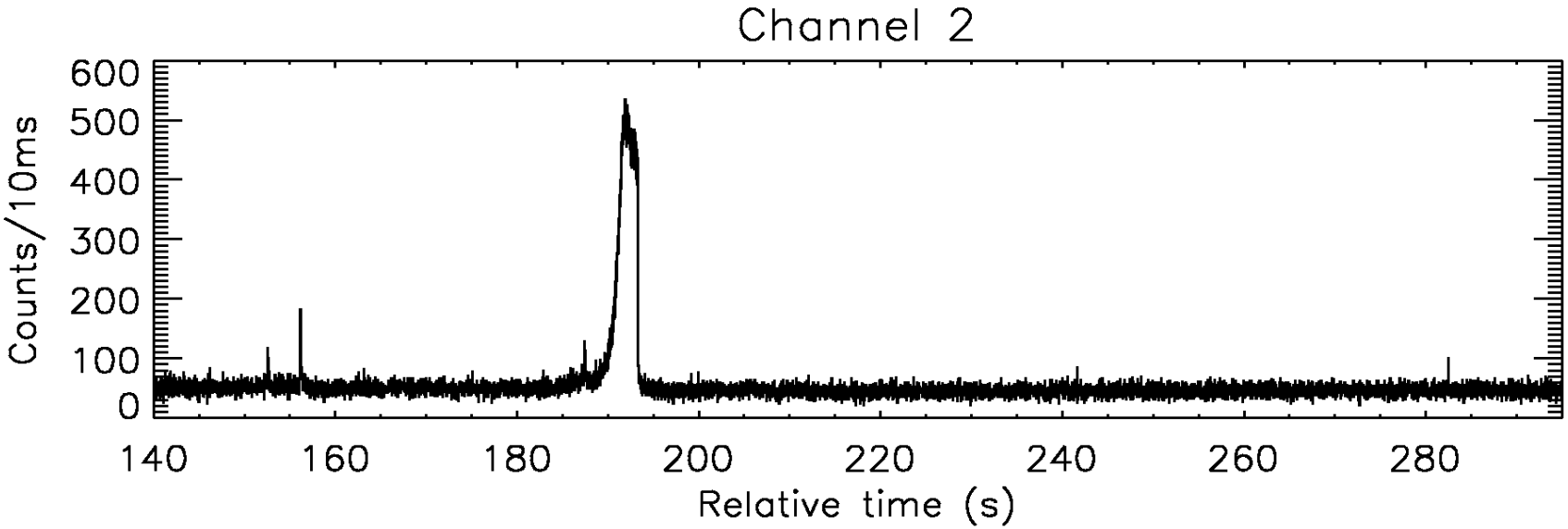
Frequency of occurrence relative to lightning, and lightning type, is one relevant question.

Size of the emitting region is another.

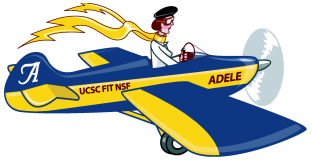


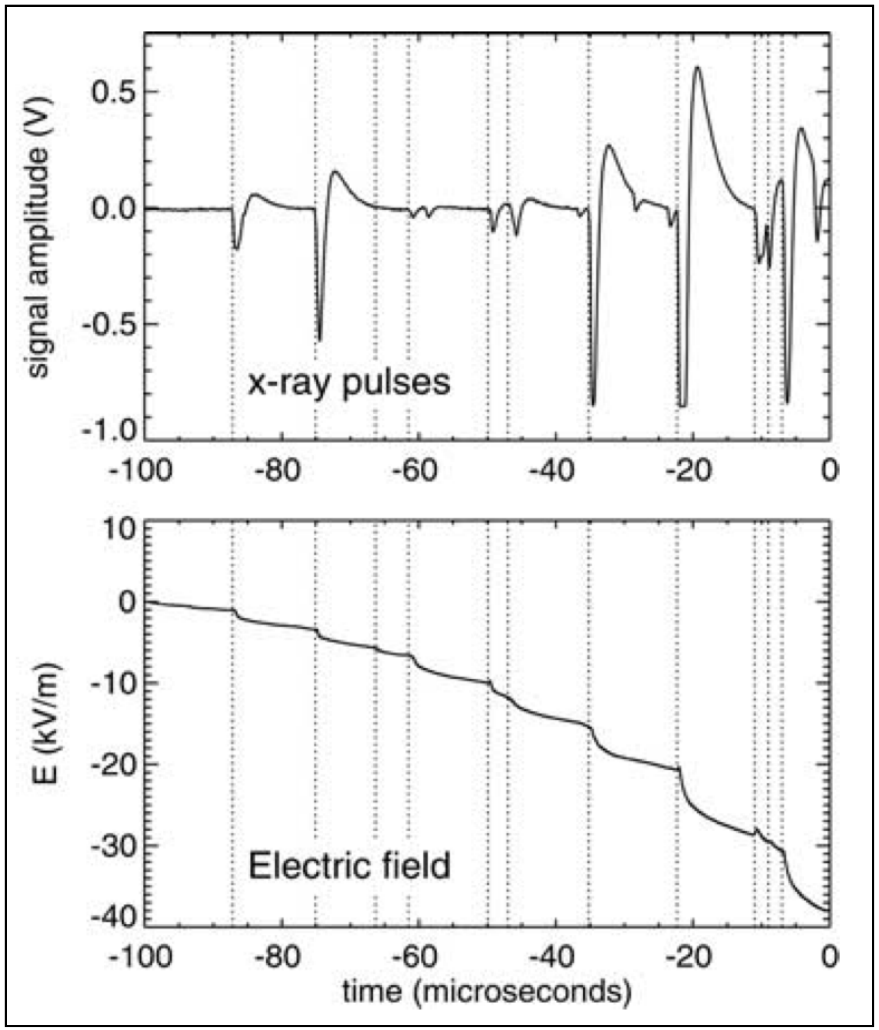


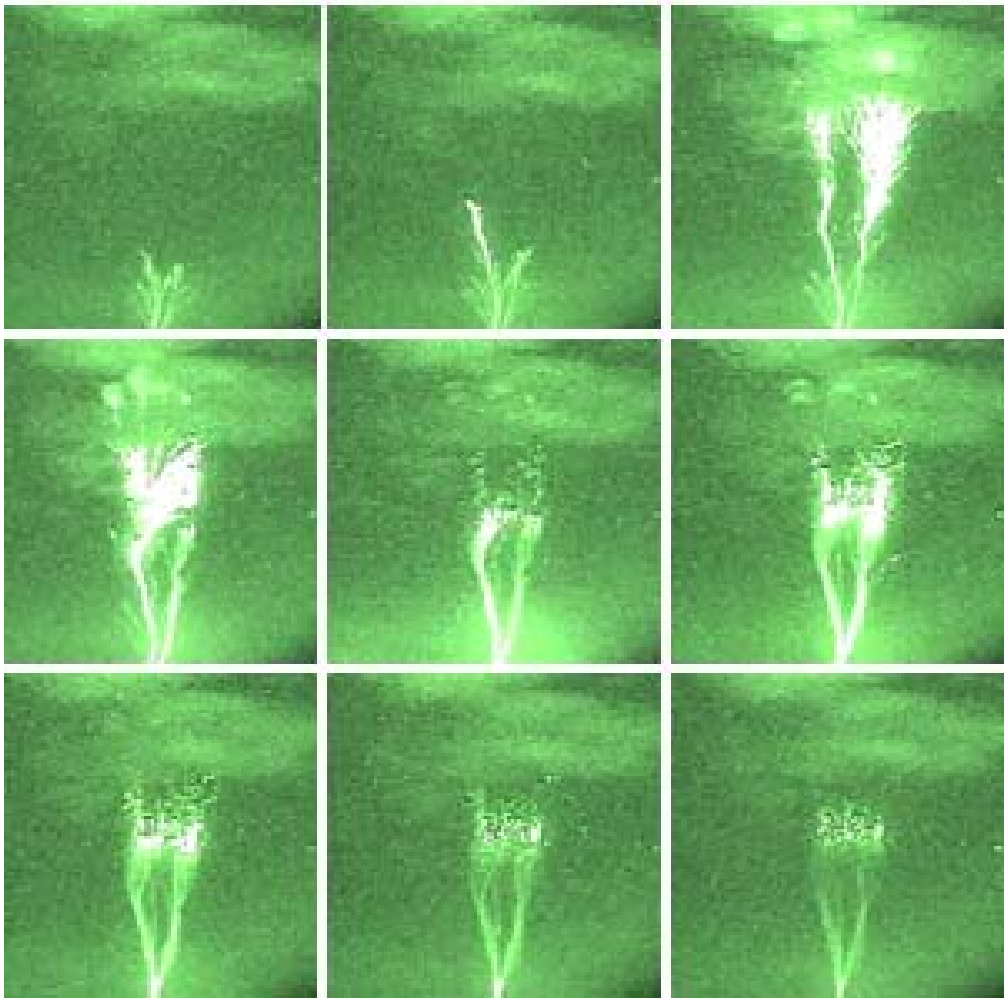
Glows seen from afar (left) and up close (below) by ADELE



Glows are often terminated by a lightning strike.







X-ray pulses seen in leader steps from the ground
(J. Dwyer et al. 2003, Science, 299, 694)

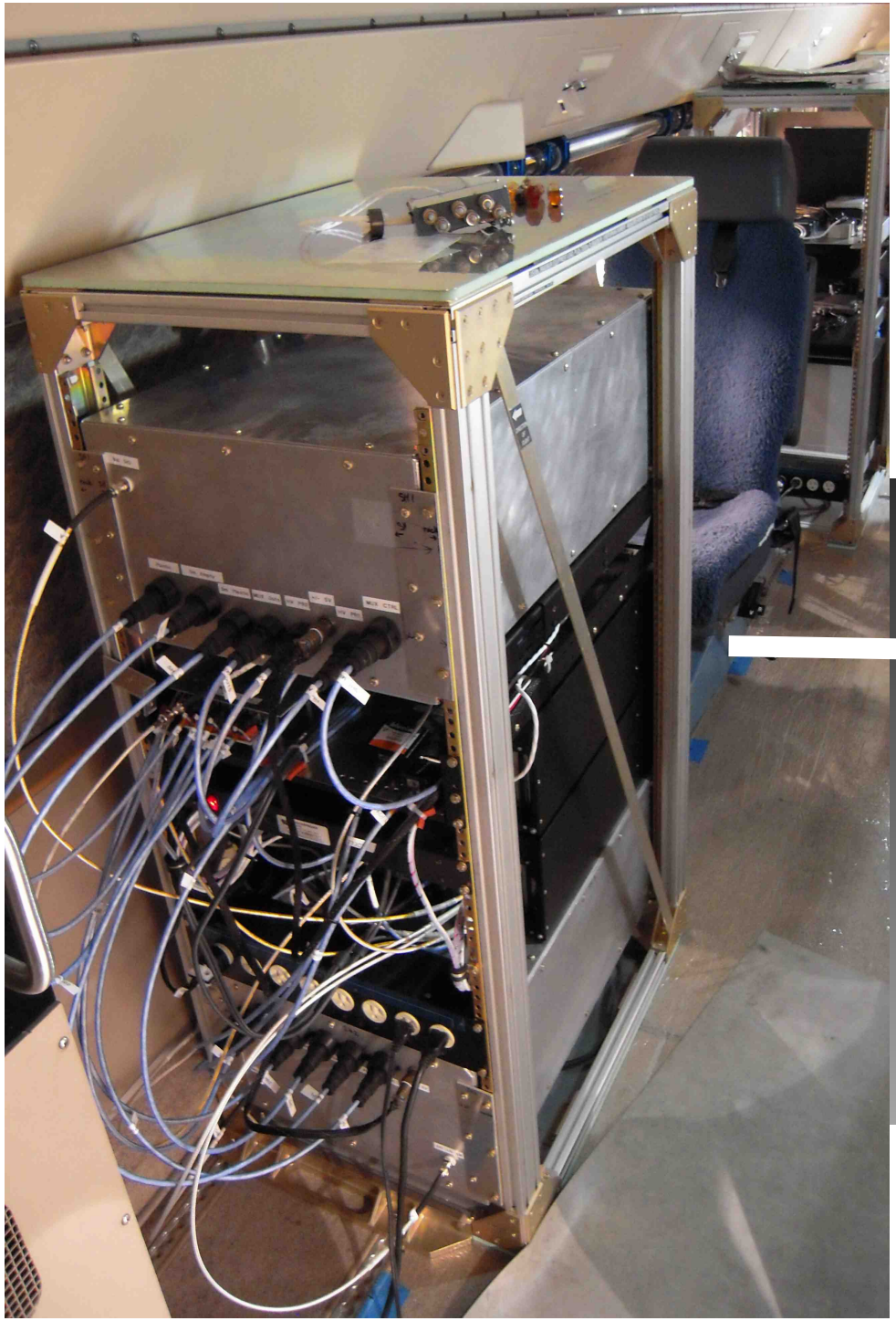
Gigantic jets are upward lightning to the ionosphere associated with **oceanic** storms – do they also show energetic radiation in steps?

(*V. Pasko et al., Nature, 2002)*

ADELE primary detector

Plastic scintillator

Instrument characteristics:
High throughput, high dynamic range,
crude energy resolution



Status:

New box in machine shop

New flight & ground software

90% complete

New power supplies purchased;

Power board being laid out